

Ultraclean Lubricants

A Specialized Process for Critical Applications

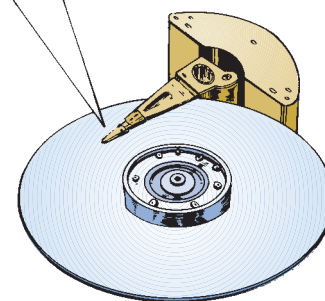
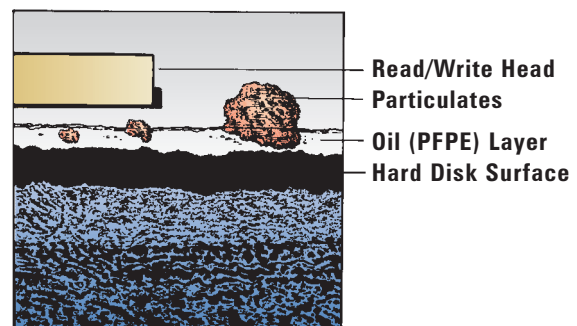
By William Galary

Often there is a fine line between success and failure. In many specialized lubricant applications the difference between success or failure could be a particle the size of a grain of sand or a molecular haze from an additive. Unfortunately, many design engineers do not pay enough attention to the cleanliness of the lubricants they specify for an application. They typically select lubricants for temperature, viscosity, wear protection, corrosion inhibition, and other functional properties. It is not until there is a high percentage of unexplained rejects or, worse, failures in the field that the spotlight turns toward the lubricant.

SMALL PARTICLES – BIG PROBLEMS

Contamination in every shape and form can alter the performance of critical applications. Molecular contamination, volatile material that can be released from lubricants, can fog the optics in satellites or wreak havoc in a semiconductor cleanroom. An open circuit in a switch could be the result of a particle wedged between the contacts. Lubricant on a disk drive provides protection for the occasional bumps that happen as the flying head cruises 500 angstroms over the surface of the disk. Without lubrication, the surface would wear quickly. The presence of solid contaminants in the oil, however, can jeopardize the protective film, turning the flying head into a virtual golf club hitting particles of debris across the surface of the disk or driving them into the disk surface. Miniature precision bearings found in disk drives, space-

craft gyros, high speed dental drills, or positioning equipment used in vacuum chambers contain balls as small as 350 microns — which means that specks you can't see with an unassisted eye (<45 microns) can pose a serious threat to the life and operation of these bearings. The life of a bearing depends on a micro-thin film of lubricant that separates the ball and the raceway. The rotation of bearings creates this elasto-hydrodynamic (EHD) film. Any solid contaminant greater in diameter than the EHD film can result in “debris denting,” where the contaminant jams between the two surfaces, damaging one or both surfaces. Further, the denting sometimes creates additional debris, which causes bearing “noise.”



Collision Course. This exploded view of the head/disk surface interface shows the collision course that the head has with contamination in the film of oil that protects the disk surface. Not only are the large particles knocked around and into the surface, the smaller particles below the film surface can cause damage during the occasional bump that happens between the head and the surface layer.

Repeated denting action can eventually lead to “peeling” or microspalling, a very shallow chipping of the surface caused by metal fatigue. In the fiber optics industry, contamination plays a more passive, but nonetheless harmful role. It does not gouge or dent. It just blocks the light — typically in fiber optic connectors, one of the few junctures on this information highway where light waves can be interrupted. Fortunately, however, lubricant contamination, with a bit of foresight, can be minimized or avoided altogether. Nye Lubricants, for over 35 years, has been involved in developing innovative procedures, test methods and equipment to provide ultraclean lubricants to the Aerospace, Semiconductor, and Photonic Industries.

WHERE DOES IT COME FROM?

Solid particles in lubricants come from many sources but raw materials, the manufacturing process, and the environment are the most common culprits. Raw materials such as the base fluids, gellants, and additives used to make lubricants may contain paper fiber, plastic debris, hair and iron oxide.

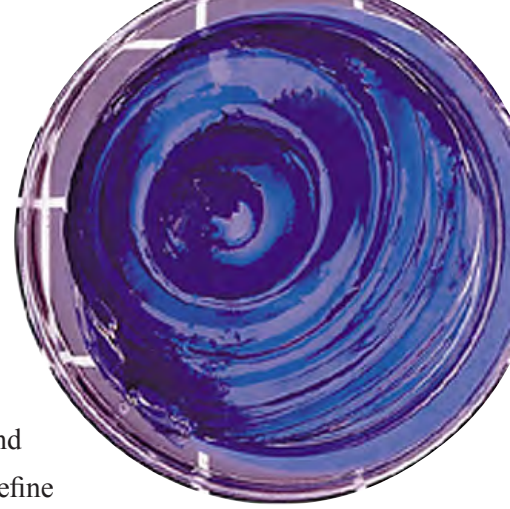
Volatile contamination lurks within the chemical structure of the base oil and additives. This chemical menace remains hidden until conditions such as temperature or vacuum release it from the lubricant to migrate to surfaces where it may cause substantial harm.



During the manufacturing process, lubricants can pick up metal from misaligned machine parts, rubber from gaskets, and carbon from kettles. Dust particles, fabric fibers, hair, glass; even nuts and bolts are just some of the environmental contaminants Nye has removed from lubricants during the past 35 years.

WHAT IS CLEAN?

The amount of solid contaminates in a lubricant determines how clean it is. The IEST (Institute of Environmental Sciences and Technology) standards define cleanliness levels for oils. IEST-STD-CC1246 includes five cleanliness levels for oil: 50, 25, 10, 5, and 1, where each number refers to the largest particle (in microns) allowed in oil. A rating of Cleanliness Level 1, for example, means that there are no particles greater than 1 micron in that oil.



The origins of cleanliness levels for grease came from military specifications. Now many civilian applications, driven by more stringent demands for quality, reliability and long operating life, have adopted these clean requirements. There are three cleanliness levels for grease at Nye: unfiltered, filtered, and ultrafiltered. An unfiltered grease can contain particles larger than 75 microns. The filtered or “clean grease” cannot have any particulate matter larger than 75 microns, and there must be less than 1,000 particles per cubic centimeter between 24 and 74 microns in size (MIL-G-81322, Aircraft Grease is an example). Ultrafiltered or “ultraclean grease” must not have any particles larger than 35 microns, nor may it have more than 1000 particles per cubic centimeter between 10 and 34 microns in size (MIL-G-81937, Ultraclean Instrument Grease for example). For some grease applications, Nye has achieved a particle count of less than 500 particles per cubic centimeter. This is fifty percent less than what is required in the military specification. Included in the ultrafiltered category is a new standard for optical products. Optical gels may not contain any particles larger than 25 microns and must have no more than 50 particles per cubic centimeter, none larger than 24 microns.

The amount of volatile content in the lubricant is tested by

either vapor pressure or outgassing per ASTM E595 which determines the Total Mass Loss (TML) and Collected Volatile Condensable Materials (CVCM). This test evaluates the changes in the mass of a test specimen on exposure under vacuum to a temperature of 125°C and the mass of those products that leaves the specimen and condense on a collector at a temperature of 25°C. NASA guidelines target a TML of 1.0% maximum and a CVCM of 0.10% maximum.

IT'S A DIRTY JOB BUT NYE IS GOOD AT IT

The best way to make an ultraclean grease is to control each step in the manufacturing process. However, most lubricant manufacturers produce large volumes of lubricants in a single batch. Since only a small percentage of a batch may be earmarked for an ultraclean application, it is not cost-efficient to create an ultraclean process for the entire batch. Many plants do filter their products at the end of the production cycle, but only to remove visible particles (primarily for appearance) before the lubricant is pumped into unwashed containers. Consequently, many oils, greases, and fluids, especially those destined for miniature devices, have to be cleaned post-production — a niche Nye Lubricants aimed to address when it established its ultrafiltration services 35 years ago. While Nye does use small batch, process control to manufacture all lubricants for ultraclean applications, the ultrafiltration department serves as a fail-safe when packaging our lubricants — and as a venue for cleaning greases from other manufacturers, which is a sizable portion of our operations.

Filtering contamination from grease once it has been gelled requires a thorough knowledge of Rheology, the science of the flow and deformation of matter, a controlled environment, and a vast arsenal of filters. Generally, the filters are either nylon or stainless steel, starting at a rating of 0.2 microns for oils and 10 mi-



cons for grease. The filters used depend on the composition of the grease and the type of contaminants. Once a set of filters is selected, the lubricant is forced through them with custom-designed, high pressure equipment in a Class 100



Clean room, clean grease. Clean air for a 10-foot mini-environment blankets the working surface, where lubricants are ultrafiltered and packaged in a Class 100 environment.

mini-environment. This ultrafiltration system can process as little as one ounce of grease, and it deposits the ultrafiltered lubricant directly into clean end-use containers.

Removing volatile contamination from base oils and additives is literally done drop by drop using a molecular still. A molecular still uses elevated temperatures under vacuum to extract volatile molecules from the fluid. In this process, wipers spread a film of oil onto the inside glass wall which can be heated to temperatures as high as 300°C. Lighter molecules in the thin fluid film evaporate and condense on a cool inner tube. The volatile distillate is collected in one flask while the more stable distilland is collected in another container. The distilland or stripped fluid becomes the new base oil for ultraclean lubricants.

KEEP IT CLEAN

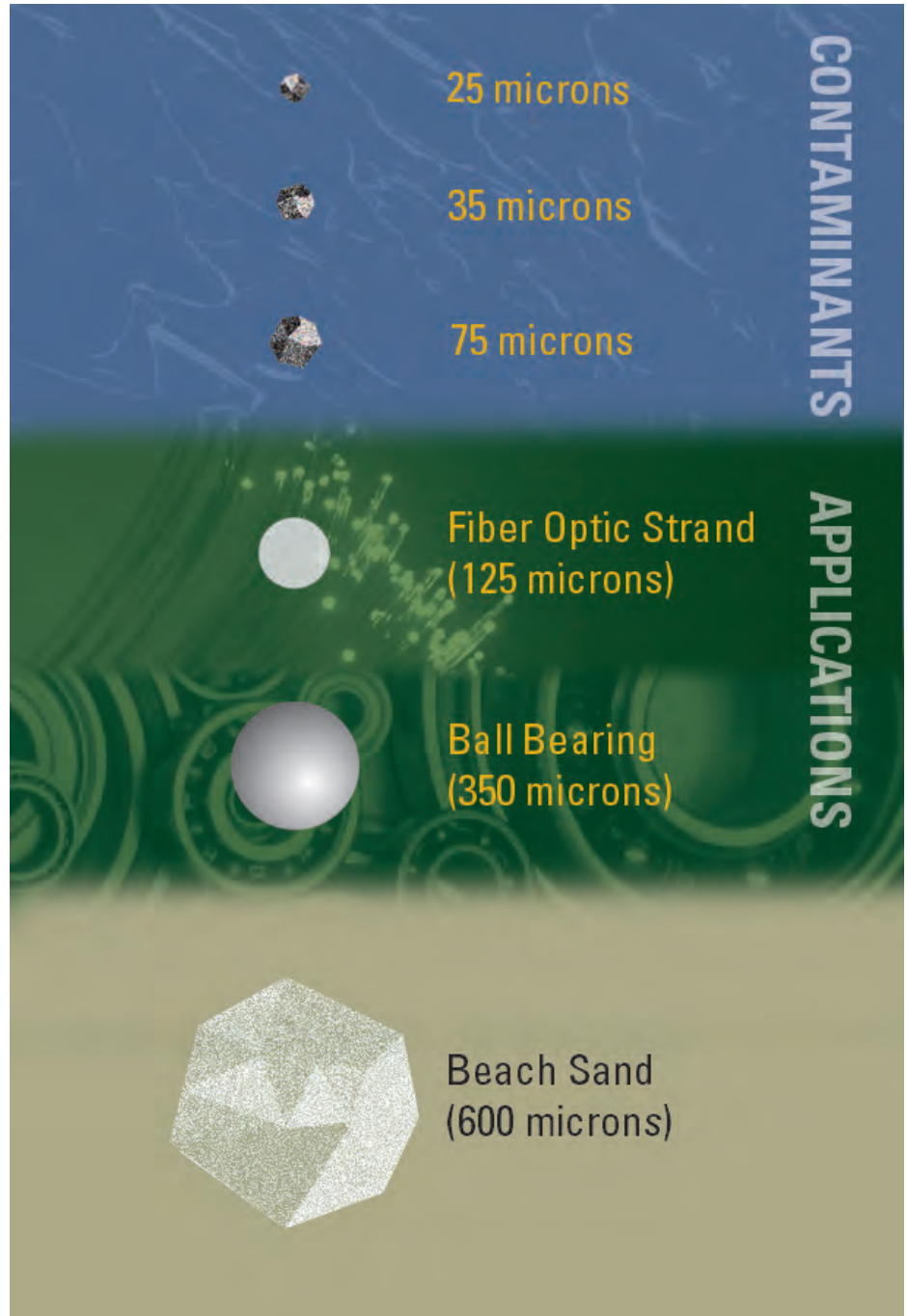
Nye's ultrafiltration process deposits the lubricant directly into the end of use containers. Before filling, each container undergoes a multi-step cleaning process using filtered deionized water. The containers are then dried with HEPA filtered hot air. Care is also taken in the selection of containers. Metal and fiber containers are not used. Glass and plastic are good material choices for most clean lubricants. Caution must be taken when using plastic containers for low outgassing lubricants. Some plastic containers will outgas. The rule of thumb is that if the container has a plastic smell, it is outgassing

CLEAN FRONTIERS

What is better than a low outgassing particle free grease? How about a grease that will prevent particles from being shed into a cleanroom. Nye is now working on low particle generating lubricants that are clean and will keep cleanrooms particle-free. These lubricants reduce friction in tooling such as ball screws and will prevent any particles generated from the tooling from escaping into the environment or finished product.

In the planning stages at Nye will be a new clean environment for the manufacture of Aerospace products, where every step in the manufacturing process will be carefully controlled. In this room all apparatus, equipment and yes, even the personnel, will be dedicated to produce the finest Aerospace lubricants possible.

Nye will constantly innovate new ways to improve our lubricants in ways that are not always visible, but our customers will see the results in the success of their products.



Light Blockade. This diagram compares the maximum size of contaminates allowed in filtered and unfiltered grease to the size of some of the components with which they interact (Ultrafiltered Optical Gel, 25 microns; Ultrafiltered Grease, 35 microns; Filtered Grease, 75 microns) For example, a filtered, not an ultrafiltered, optical gel could have a 75 micron particle in it — more than half the diameter of a fiber optic strand. Less than half the light waves would make it through this blockade. (Note, while the elements in the diagram are enlarged, they are proportionally accurate. The grain of beach sand is added to illustrate scale.)